

ASYMMETRIC BOSE-EINSTEIN EFFECT

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Recent results on modelling Bose-Einstein effect in Monte Carlo generators for a source with no spherical symmetry (as seen in the data on Z^0 hadronic decays) are reported. Modifications of the weight method necessary for W^+W^- decays are presented and some preliminary results concerning the "inter- W " interference effects are discussed.

1 Introductory remarks

Recently one observes a renewal of interest in analysing the space-time structure of sources in multiparticle production by means of Bose-Einstein (BE) interference¹ which followed the example of astrophysical investigations². The main motivation of this renewal was the controversy concerning the $e^+e^- \rightarrow W^+W^-$ process³. The existence of interference effects between strings from two W -s is still debatable⁴. Another reason to analyze the BE effect were the efforts to estimate the shape and the lifetime of the source of particle production (e.g., for the LEP data at the Z^0 peak⁵).

Investigating such subtle effects became possible when one started to model this effect in Monte Carlo generators. There are several methods of modelling: using the "afterburner" for which the original MC provides a source^{6,7}, shifting the momenta⁸ or adding weights to generated events^{9,10}. Another approach was set forward by Andersson and collaborators who rejected the assumption of incoherence, basic for the "standard" models, and used the symmetrization inside a fragmenting string¹¹ to model the effect for a single string¹². In this talk^a we consider the most widely used methods of shifting momenta and weighting events.

In a recent paper¹³ we compared the 3-dimensional data for BE effect from LEP with the results of the standard momentum shifting procedure and of the weight method. In both cases differences between the longitudinal and transverse radii appear, but the results disagree with data. Introducing asymmetric weight factors one may describe the data satisfactorily. This is presented in the second section.

In the last section we return to the problem of "inter- W " interference. We

^aPresented by K. Fiałkowski

point out that the BE effect for pairs of pions from different W -s is in principle unavoidable, and the only problem is a reliable estimate of its magnitude. We mention some preliminary results for the obtained effect using a modified weight method applicable in this case.

2 Asymmetry in Z^0 decays

We discuss only the L3 data¹⁴ which measured the BE ratios using "uncorrelated background"

$$R_2(p_1, p_2) = \frac{\rho_2}{\rho_2^{mix}} / \frac{\rho_2^{MC}}{\rho_2^{mix, MC}}$$

and three different radii to parametrize the data. The DELPHI data¹⁵ are parametrized with only two radii, and the OPAL data¹⁶ use the like/unlike ratio which requires cutting off the resonance affected regions even in double ratios.

We refer to our paper¹³ for the choice of variables and definitions of parameters. In the data¹⁴ the fitted value of the parameter λ is 0.41 ± 0.01 , and the values of radii (in fm) are:

$$R_L = 0.74 \pm 0.02_{-0.03}^{+0.04}, \quad R_{out} = 0.53 \pm 0.02_{-0.06}^{+0.05}, \quad R_{side} = 0.59 \pm 0.01_{-0.13}^{+0.03}$$

As shown in the L3 paper, the standard LUBOEI procedure built into the JETSET Monte Carlo generator gives

$$R_L = 0.71 \pm 0.01, \quad R_{out} = 0.58 \pm 0.01, \quad R_{side} = 0.75 \pm 0.01.$$

We confirmed these numbers in our calculations and checked how the results depend on the parameters λ_{in} and R_{in} assumed in the LUBOEI input function. In all cases we get (contrary to the data) $R_{side} > R_L > R_{out}$, although the input function was obviously symmetric. No choice of input parameters gives the values of R_i compatible with data.

The known problems of LUBOEI procedure^{17,18,19} led to a revival of weight methods, known for quite a long time²⁰, but plagued also with many practical problems, some of which have been recently solved¹⁰. In this method we may repeat the same calculations as done for the LUBOEI procedure. The major features of the results are surprisingly similar: with weight factors depending only on Q^2 we get different values of fitted R_i parameters. Moreover, the hierarchy of parameters is the same: $R_{side} > R_L > R_{out}$. This suggests that the asymmetry is generated by the jet-like structure of final states and not by any specific features of the procedure modelling the BE effect. Again, no choice of the input parameters allows to describe the data.

One may get more information on the problem of asymmetric BE effect in MC generators using the asymmetric weight method, i.e. introducing weight factors which depend in a different way on $Q_L = |p_{1L} - p_{2L}|$, $Q_{side} = |p_{1side} - p_{2side}|$ and $Q_{out} = |p_{1out} - p_{2out}|$, where the indices denote the momentum components defined in the usual way¹³

$$w_2(Q_L, Q_{out}, Q_{side}) = \exp([-Q_L^2 (R_L^{in})^2 - Q_{out}^2 (R_{out}^{in})^2 - Q_{side}^2 (R_{side}^{in})^2]/2)$$

This weight factor reduces approximately to the symmetric weight factor

$$w_2(p_1, p_2) = \exp[-(p_1 - p_2)^2 R_{in}^2/2]$$

when $R_L^{in} = 2R_{out}^{in} = R_{side}^{in} = R_{in}$. The weight attached to the event is given by⁹

$$W(p_1, \dots, p_n) = \sum_P \prod_i w_2(p_i - p_{P(i)}).$$

Since for the symmetric weights the resulting fitted values of R_{side} are bigger than the values of R_L (contrary to the inequality seen in the data), it seemed natural to take the input value of R_{side}^{in} smaller than R_L^{in} . The best set we found is

$$R_L^{in} = 0.9fm, R_{out}^{in} = 0.3fm, R_{side}^{in} = 0.4fm.$$

Then we get the following fitted values of the parameters

$$R_L = 0.73fm, R_{out} = 0.54fm, R_{side} = 0.65fm$$

in agreement with data.

There is a striking difference between the input values of the radii assumed in the weight factors and the resulting best fit values from the double ratio calculated with these weights. Although the hierarchy $R_L > R_{side} > R_{out}$ is the same in both cases, the fitted values differ by less than 25%, whereas there is a difference by more than a factor of two between the input values.

Moreover, further decrease of the values of R_{out}^{in} and R_{side}^{in} hardly affects the resulting double ratio and fitted values of R_i . This seems to be the inherent property of the JETSET generator, which yields a rather strong suppression of large values of Q_i and Q^2 even without any procedure imitating the BE effect. Apparently this suppression dominates over the weak enhancement of low values of Q_i induced by the weight factors with small values of R_i . For small R_i^{in} there is no simple correspondence between the input and output values of radii. This looks analogous to the effect noted already for a symmetric BE effect described by the LUBOEI procedure¹⁹. Therefore any direct interpretation of the fit values for BE double ratios in terms of the different radii of the asymmetric source is a rather delicate matter.

3 Interference between pions from different W-s

There is no experimental evidence of interference effects between pions from different W -s. Moreover, some data are shown together with "MC predictions including inter- W BE effect" which clearly disagree with data⁴. This seems to suggest that the "inter- W BE effect" does not exist and that the models where BE effect is confined to a single string^{11,12} are preferred.

We want to stress that this suggestion is false. The BE effect for two pions coming from (incoherent) decays of two W -s is an inevitable consequence of quantum mechanics and any model neglecting it is not complete. However, for given kinematic configuration this effect may be negligible. The "MC predictions" for this effect shown with the data are completely unrealistic, as they assume *the same effect for pairs of pions coming from the same, and from different W -s*. There is no reason to believe that this is true. We are now working on the realistic estimate of this effect for the weight method. For the decay of two W -s the assumption of no correlations between the creation point and momentum is obviously wrong. The simplest necessary modification of the standard formula for weight is to take into account the different space location of two sources. We get then

$$W(p_1, \dots, p_n) = \sum_P \prod_i w_2(p_i - p_{P(i)}) \cdot \prod_k w_2(p_k - p_{P(k)}) \cdot W'(\Delta p)$$

where $\Delta p = [\sum_i (p_i - p_{P(i)}) - \sum_k (p_k - p_{P(k)})]/2$. Here two products (sums) extend over particles coming from two W -s and W' is the Fourier transform of a distribution of distance between two sources (W -s). This prescription for weights may lead to results significantly different from the standard ones²¹.

Preliminary results with realistic W' suggest that even at threshold of the WW production process (where the spatial distance between two sources is minimal) the effect for pions from different W -s is weak, and at energies dominating present data sample it is completely negligible.

Summarizing, we have shown that the weight method of implementing the BE effect into MC generators is quite useful for various applications. It may describe the effects for which other methods fail.

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